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*RESOURCE MANUAL*

# BUFLO

## *BUFFALO HERD POPULATION MANAGEMENT*

Developed by:

Ludwig Braun, State University of New York
Stony Brook, New York
James Friedland, Douglas MacArthur High School
Levittown, New York

Programmed by:

Burt Esrig, State University of New York
Stony Brook, New York
Michael Weisner, State University of New York
Stony Brook, New York
Ludwig Braun
James Friedland

Illustrations by:

Marie Rulon, State University of New York
Stony Brook, New York

HUNTINGTON TWO COMPUTER PROJECT

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(Revised November 29, 1973)

1 March 1974

THE WORK OF THE HUNTINGTON TWO COMPUTER PROJECT IS PARTIALLY SUPPORTED BY THE NATIONAL SCIENCE FOUNDATION, GRANT GW-5883.

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*BUFLO*

## RESOURCE MANUAL

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## I. ABOUT THE BUFFALO

### "BUFFALO" by Dick Pryce, *SCOUTING MAGAZINE**

In 1867, the Kiowa Indian Chief, Satanta, predicted the annihilation of the buffalo. Hardly anyone, white or red, took his warning seriously. Every spring a seemingly inexhaustible supply moved northward in the annual migration. Thousands upon thousands of buffalo would blacken the earth clear to the horizons. The Indians believed the buffalo were magically produced in limitless quantities in a gigantic cavern hidden somewhere in the vast reaches of the *Llano Estacado*, the semiarid Staked Plain region of Texas and New Mexico. The white man knew that the shaggy beasts always had been as numerous on the plains as countless blades of prairie grass. The immense tableland lying east of the Rocky Mountains, from Mexico to Canada, had always been one great big buffalo pasture.

A treaty was signed by the Plains Indians in which they agreed to abandon their free way of life, which included living on reservations and withdrawing all opposition to the railroads. In return, the peace commissioners promised annuities to feed and clothe the tribes and allowed them off-reservation hunting rights -- on lands the Indians had regarded as theirs for hundreds of years.

Railroad construction by the Union Pacific had reached Cheyenne, Wyoming by this time. The coming of the railroad heralded the beginning of the end to the American bison -- a name seldom if ever used by frontiersmen such as William F. Cody.

Cody was employed as a meat hunter for still another railroad, the Kansas Pacific. To feed the railroad's construction workers, in 17 months he killed nearly 4,300 buffalo, earning in the process $500 a month, the lifelong nickname of Buffalo Bill and a permanent niche in American history.

In 1868 the Kansas Pacific began selling tickets to sportsmen who would slaughter a few buffalo, then hop back on the train to return to the East. Some passengers didn't even leave their seats. They simply started banging away when the train passed through a herd. Nearly always the meat was left to rot. These senseless killings infuriated the Indians, and periodically they would vent their anger on small groups of white men. But aside from driving the herds back from the railroad rights-of-way, this merry diversion hardly seemed to dent the supply.

By this time the buffalo had been divided into what came to be called the Northern Herd and the Southern Herd, a trend that had been evident for years. The division apparently began in 1849, when tremendous numbers of men followed the Platte River of southern Nebraska westward toward the gold fields of California. At first these trailblazers could kill all the buffalo needed for food without stepping off the trail. But before long not a buffalo could be found within shooting distance of the Platte. When the Union Pacific was built along this river, the buffalo were divided forever -- with the greatest numbers living south of the Platte in the Southern Herd.

Despite the separation, the animals were plentiful. Steamboats on the upper Missouri would stop and wait when a herd wanted to cross the river. In the frontier cowtown of

---

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Wichita, choice buffalo humps sold for three cents a pound. In May of 1871 Col. Richard I. Dodge traveled along the Arkansas River in central Kansas from old Fort Zarah to Fort Larned, a distance of 35 miles, through a huge herd moving northward.

"At least 25 miles of that distance," he later recalled, "was through one immense herd," adding that it took this bunch 5 days to pass a given point.

At approximately the same time that Colonel Dodge picked his way through a herd later estimated to contain 4 million buffalo, industrialists in the East suddenly discovered that buffalo leather, for many purposes, was unexcelled. One firm ordered several thousand hides, and almost overnight a strange breed of men, the professional hide hunter, was born. Armed with recently perfected long-range breechloading rifles, hide hunters could sneak to within 200 or 300 yards of a herd and pump lead into it as long as the herd was within range. Not since gold fever had gripped the restless in '49 had so many Americans flocked to one section of the country. The railroads brought hunters in by the trainload, carrying buffalo hides on the return trip.

On September 23, 1872, tracks of the Santa Fe Railway reached the Kansas hamlet of Dodge City, which soon became the headquarters from which the extermination of the Southern Herd was to be directed. By December there were at least 2,000 hide hunters employed in the buffalo-killing industry. The hide of a full-grown bull -- which would stand six feet at the shoulders and weigh 1,800 pounds -- brought 75 cents to $2.50, depending on its condition. Good winter robes commanded from $4 to $6. Salted tongues, about the only meat saved, earned hunters a quarter and sold for 50¢ in the East. By January 1, 1873, the Santa Fe had hauled 43,000 hides from Dodge. A few persons started to wonder if Satanta had been right when he predicted the whites would kill off the buffalo.

"Each hide counts a buffalo slain," the editor of one frontier newspaper wrote when he learned how many hides were shipped from Dodge, "and 43,000 hides in three months convey an idea of magnificent butchery that forecasts the speedy extinction of the prairie denizen."

The editor's arithmetic appears logical, but it wasn't. The 43,000 hides probably represented at least 150,000 dead buffalo, maybe more. Experts like Colonel Dodge estimated that for every hide that reached the market, from two to five animals were killed, because most of the hide men were not frontiersmen and they ruined many of the hides during the skinning process.

The "magnificent butchery" continued unabated. As buffalo became harder to find, better organization was necessary. The normal hunting party was made up of the hunter, four skinners and a cook. Buffalo usually were shot in the morning after they had been to water and were lying down to rest. The hunter, using two guns and a forked stick or tripod as a support, often killed 50 animals without moving from his track; 200 a day was a normal kill -- for a skinner could rip the hides from about 25 buffalo in a day.

William Blackmore, a London sportsman who traveled for 40 miles along the Arkansas River in the Fall of 1873, reported: "There was a continual line of putrescent carcasses, so that the air was rendered pestilential and offensive to the last degree. The hunters had formed a line of camps along the banks of the river and had shot down the buffalo, night and morning, as they came to drink. In order to give an idea of these carcasses, it is necessary to mention that I counted 67 on one spot not covering four acres."

This slaughter was repeated on the Platte, the Smoky, the Pawnee, the Republican, the Solomon, the Walnut and the Saline Rivers, and their tributaries.

"Every drink of water, every mouthful of grass," said a Cavalry officer who witnessed the orgy, "is at the expense of life, and the miserable animals, continually harassed, are driven into localities far from their natural haunts, anywhere to avoid the increasing pursuits."

Voices crying out against the slaughter became more voluble. In 1874 a bill was introduced in the Texas Legislature to protect buffalo. However, General Phil Sheridan, the Civil War hero, appeared before the lawmakers and pointed out that buffalo were the commissary of the Indians, insisted that the extermination was necessary to our colonial expansion.

"One party of 16 hunters killed 28,000 buffalo last summer," the United States Congress was told. That was an average of 1,750 buffalo per hunter, slain at a season when meat was impossible to save and worthless as food.

But it was too late for tears. Nothing could save the vast herds of buffalo. The Kansas Pacific, Union Pacific and Santa Fe during a 3-year period (1872-74) shipped to the East 1.3 million hides, 6.7 million pounds of meat and 32 million pounds of buffalo bones -- used mostly for fertilizer. Considering the wasted animals, probably 4.3 million buffalo -- the bulk of the Southern Herd -- were killed in these 3 years. Congress talked of interfering, but didn't. The buffalo melted like snow beneath a hot summer's sun. At the close of the hunting season of 1875, the remnant of the great Southern Herd fled south toward the *Llano Estacado*.

The Dodge City-based hunters headed south also, despite the fact that the Medicine Lodge treaty forbade them to do so. More hunters made their headquarters at Fort Worth, Texas. From 1876 to 1878 there were 300,000 additional skins marketed by 1,500 hunters, who for all practical purposes wiped out the Southern Herd.

The Northern Herd -- which numbered a about 1.5 million -- survived a few more years on the high plains of the Dakotas, Montana and Wyoming. In 1880, summer hunt began in the north, and the herd had all but vanished by the end of the 1882-3 season. And in another 3 years Indians in Canada were starving because most of the buffalo there were gone.

A few wary buffalo continued to exist here and there. In 1887 a Texas rancher discovered a herd of about 200 in the Panhandle between the two forks of the Canadian River. His party killed 75. By this time the buffalo were so rare that the heads brought $50 apiece, the robes $200.

Teddy Roosevelt, hunting in the fall of 1889 in Idaho, was deeply moved when he trained his sights on what certainly must have been among the last of the survivors.

"Mixed with the eager excitement of the hunter," noted Roosevelt, "was a half-melancholy feeling as I gazed on these bison, themselves part of the last remnant of a doomed and nearly vanished race."

And vanish they nearly did. By 1890 there were fewer than 1,000 buffalo in the United States. At this point a few individuals and the federal government began giving long-withheld protection. Happily the buffalo never vanished, and there probably are 20,000 in scattered

Canadian and American herds today. Naturalists estimate there must have been 70 million buffalo in the 1700's. By 1800 there were no buffalo east of the Mississippi, but 40 million in the 3 million square miles of open plains. It wasn't until the buffalo were nearly gone that these attempts to count them were made. The revelations were appalling, but to the end the hide hunters showed no pity for the buffalo.

"Pity?" a puzzled veteran hide hunter said in 1930 a half century after the big kill. "No, I did not feel it. It was business with me. I had money invested .... if I did not butcher the buffaloes, there were many other hunting outfits around me that would, so I killed all I could.

"I and the thousands of other buffalo hunters had no high-minded motives in slaughtering the buffalo. We were after his hide and the money it would bring, but yet the buffalo hunter was the true pioneer who cleared the way for the cowboy and steer, the settler with his plow, the church and school and civilization ... When we killed off the buffalo, the Indian's commissary was gone, he was starved into submission, went upon his reservation. The country never could have been settled so long as the buffalo was here to support the Indian."

## II. HOW *BUFLO* SIMULATES THE NATURAL LIFE CYCLE OF THE AMERICAN BISON

The buffalo's life cycle starts with the birth of the new calves. Birth takes place after the melting of the winter's snows in April or May, depending on the location. The *BUFLO* program reports the population immediately following calving. Because of this, the population may occasionally rise above the carrying capacity, the greatest number of buffalo which the range can support. This surplus population will usually be eliminated through predation and natural mortality.

Soon after birth, the new calves are able to travel with the rest of the herd and for the rest of their first year they will be dependent on their mother for protection and nutrition. Should the mother be killed, the calf will die as well. *BUFLO* takes this effect into account. If female adults are harvested (killed by hunters), a corresponding drop in the number of calves surviving to become yearlings will be noticed in a report the following spring.

Hunting parties seldom started until calving was finished because snows limited the hunter's access to the herds. But once started, hunting continued into the late fall, until weather made conditions unbearable (and unprofitable) for the hunter. Thus, the harvest was spread over the entire summer and fall. *BUFLO* takes this hunting distribution into consideration in simulating mating activity. This is necessary since mating usually takes place in August, about halfway through the hunting season. For the purposes of establishing fertility, *BUFLO* assumes that one half of the harvest takes place before mating.

During the August mating, males join the female herds and mating activities start as females come into heat. The most dominant male usually mates with the first female to come into heat, the second male with the second female and so on. However, the males are polygamous. As soon as the mating activity of a pair is over, the male will attempt to mate with any other female coming into heat. In this way, a single dominant male buffalo may mate with several females in a single year. *BUFLO* assumes that a male buffalo may mate with a maximum of 10 females during a single mating season. If the number of male buffalo comes to be less than 10% of the female population, *BUFLO* assumes that several of the females will not become pregnant, and will not produce calves the following spring. This effect can be seen by hunting out all the adult males.

A female buffalo can mate during her third year and produce a single offspring each year for thirty years. Observations of buffalo herds have established that mating patterns nearly guarantee the pregnancy of every fertile female. *BUFLO* assumes that if males are available, every female will become pregnant (see above); but that only a certain number of these pregnancies will be successful in producing live offsrping.

Mortality from natural causes reaches its peak during the winter months. During this time heavy snows may cover the grasses needed by the buffalo, and travel becomes much more difficult. Large kills have been recorded when the buffalo herd had attempted to cross half-frozen rivers. Animals in the back of the herd pushed those in front through the broken ice.

*BUFLO* assumes that the winter mortality rate is independent of hunting that has taken place during the previous summer. *BUFLO* also assumes that the winter herd population has an effect on the birth rate the following spring. If the population of the herd entering the winter is very near the carrying capacity, then conditions will be very hard on the individual buffalo and this will result in fewer live births the following spring. This effect can be seen by doing no hunting, and viewing the graph of the calves as the population nears the carrying capacity.

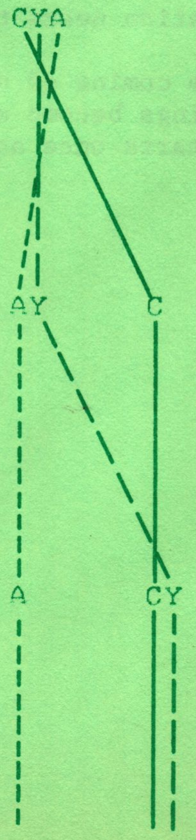
With the coming of spring, the calves are now yearlings and the previous year's yearlings become adults. With the birth of the new calves, the buffalo life cycle starts once again.

## III. ANNOTATED SAMPLE RUNS

***RUN #1*** In this run the student starts with a population of 400 buffalo and lets them reproduce until there are 800 in the herd. At that point the student attempts to halt further growth of the population through selective harvesting.

---

```
HAVE YOU USED BUFLO BEFORE (1=YES, 0=NO) ?0

CONSULT THE STUDENT MANUAL FOR INFORMATION ON
INITIALIZATION OF THE MODEL.

BUFLO USES THE FOLLOWING CODE:
    AM=ADULT MALES          AF=ADULT FEMALES
    YM=YEARLING MALES       YF=YEARLING FEMALES
    CM=CALF MALES           CF=CALF FEMALES

THERE ARE TWO POLICIES OF HERD MANAGEMENT AVAILABLE.
TOTAL FREEDOM OF HERD CONTROL (1)
OR AUTOMATIC SAFEGUARDS FOR HERD POPULATION (2)
WHICH POLICY DO YOU PREFER ?1

YEARS FOR OBSERVE, CHANGE POLICY, REPORT ?20,2,1

CARRYING CAPACITY ?4000

STARTING YEAR= ?1974

WILL YOU INITIALIZE NUMBER OF BUFFALO BY
BREAKDOWN (1) OR TOTAL HERD (2) ?2
TOTAL BUFFALO IN HERD ?400
                    HARVEST      PERCENTAGE OF ORIGINAL POPULATION
SYM/GROUP  POP      QUOTA    0           100          200          300
---------  ---      -----    I------------I------------I------------I
SPRING OF YEAR  1974                      CYA
HERD SIZE= 400
A  AM  151          ?0
A  AF  135          ?0
Y  YM  24           ?0
Y  YF  18           ?0
C  CM  36           ?0
C  CF  36           ?0

SPRING OF YEAR  1975                      AY    C
HERD SIZE= 446
A  AM  152
A  AF  134
Y  YM  22
Y  YF  22
C  CM  60
C  CF  56

SPRING OF YEAR  1976                      A     CY
HERD SIZE= 472
A  AM  152          ?0
A  AF  136          ?0
Y  YM  36           ?0
Y  YF  34           ?0
C  CM  59           ?0
C  CF  55           ?0
```



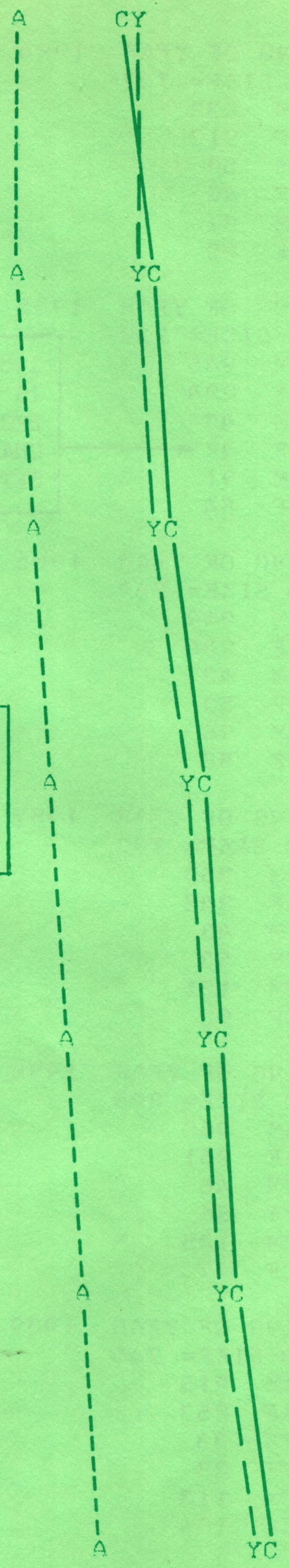
STUDENT WILL CARRY OUT A TWENTY YEAR STUDY, CHANGE HARVESTING EVERY SECOND YEAR AND GET A POPULATION REPORT EVERY YEAR.

NO HARVEST OF ANY GROUP

STUDENT HAS CONNECTED POINTS ON THE NORMALIZED GRAPH
A=ADULTS Y=YEARLINGS
C=CALVES

```
SPRING OF YEAR  1977
HERD SIZE= 491
A  AM  162
A  AF  146
Y  YM  35
Y  YF  33
C  CM  60
C  CF  55

SPRING OF YEAR  1978
HERD SIZE= 518
A  AM  171              ?0
A  AF  155              ?0
Y  YM  36               ?0
Y  YF  33               ?0
C  CM  64               ?0
C  CF  59               ?0

SPRING OF YEAR  1979
HERD SIZE= 546
A  AM  179
A  AF  163
Y  YM  38
Y  YF  35
C  CM  68
C  CF  63

SPRING OF YEAR  1980
HERD SIZE= 575
A  AM  188              ?0
A  AF  171              ?0
Y  YM  41               ?0
Y  YF  38               ?0
C  CM  71               ?0
C  CF  66               ?0

SPRING OF YEAR  1981
HERD SIZE= 606
A  AM  198
A  AF  181
Y  YM  43
Y  YF  40
C  CM  75
C  CF  69

SPRING OF YEAR  1982
HERD SIZE= 638
A  AM  209              ?0
A  AF  191              ?0
Y  YM  45               ?0
Y  YF  41               ?0
C  CM  79               ?0
C  CF  73               ?0

SPRING OF YEAR  1983
HERD SIZE= 671
A  AM  220
A  AF  201
Y  YM  47
Y  YF  44
C  CM  83
C  CF  76
```

STUDENT CONTINUES TO
DO NO HARVESTING.
POPULATION GROWS.
NOTE THAT POINTS ON
GRAPH GO TO THE RIGHT.



```
SPRING OF YEAR  1984
HERD SIZE= 707
A  AM  232              ?0
A  AF  212              ?0
Y  YM  50               ?0
Y  YF  46               ?0
C  CM  87               ?20
C  CF  80               ?0
```

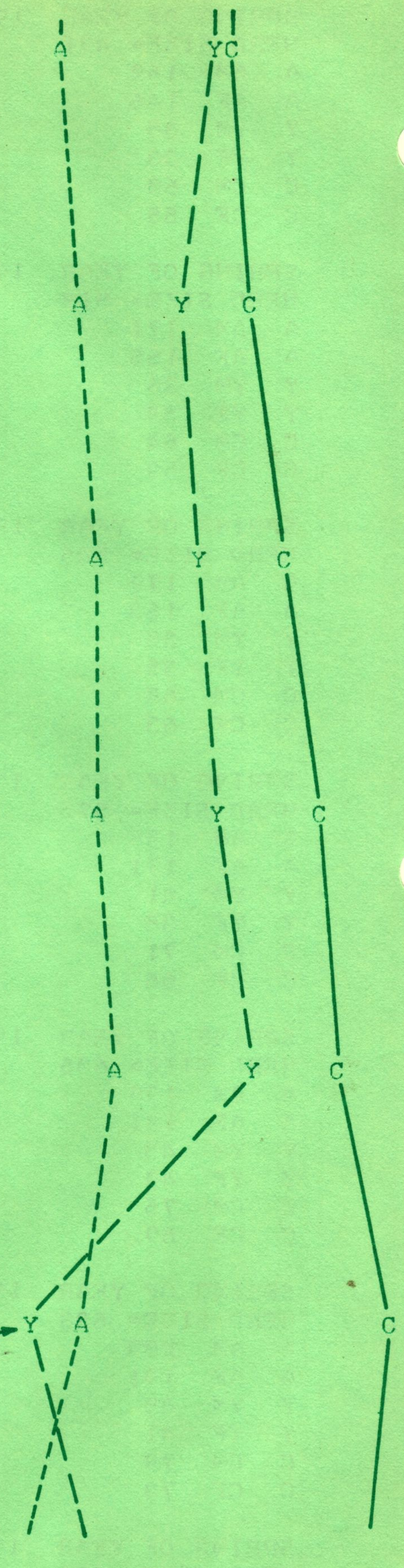
STUDENT HAS ELECTED
TO HARVEST 20 MALE
CALVES PER YEAR.

```
SPRING OF YEAR  1985
HERD SIZE= 732
A  AM  245
A  AF  224
Y  YM  40
Y  YF  48
C  CM  91
C  CF  84
```

1984 HARVESTING POLICY
IS STILL IN EFFECT
BECAUSE THE POLICY
CHANGE INTERVAL WAS
SET FOR TWO YEARS.

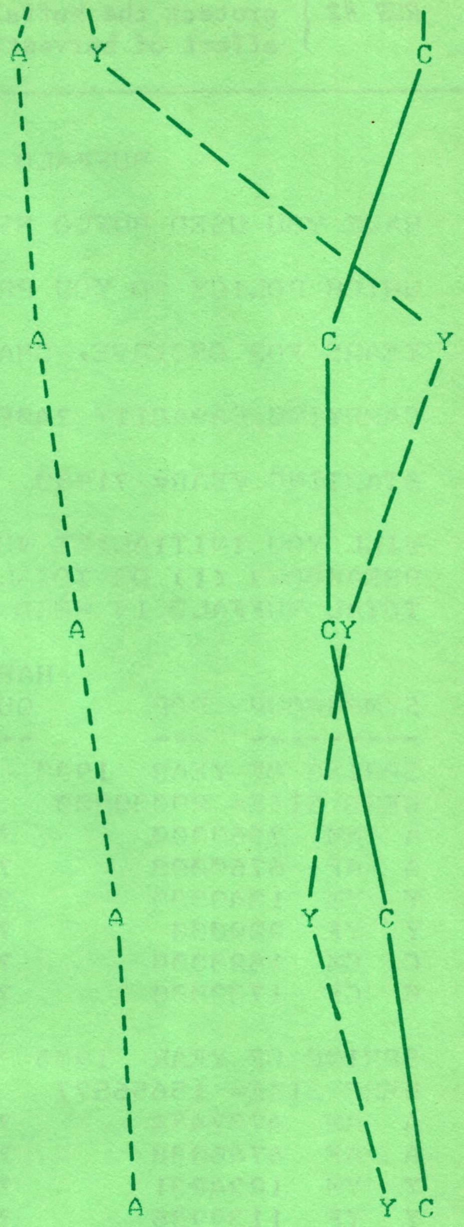
```
SPRING OF YEAR  1986
HERD SIZE= 762
A  AM  249              ?0
A  AF  236              ?0
Y  YM  43               ?0
Y  YF  50               ?0
C  CM  96               ?25
C  CF  88               ?0

SPRING OF YEAR  1987
HERD SIZE= 793
A  AM  255
A  AF  248
Y  YM  43
Y  YF  53
C  CM  101
C  CF  93

SPRING OF YEAR  1988
HERD SIZE= 825
A  AM  260              ?50
A  AF  261              ?0
Y  YM  46               ?10
Y  YF  56               ?30
C  CM  105              ?50
C  CF  97               ?50

SPRING OF YEAR  1989
HERD SIZE= 746
A  AM  215
A  AF  253
Y  YM  33
Y  YF  28
C  CM  113
C  CF  104
```

RELATIVELY LARGE
CALF HARVEST LOWERS
YEARLING POPULATION
IN SUCCEEDING YEARS
AS SHOWN ON GRAPH



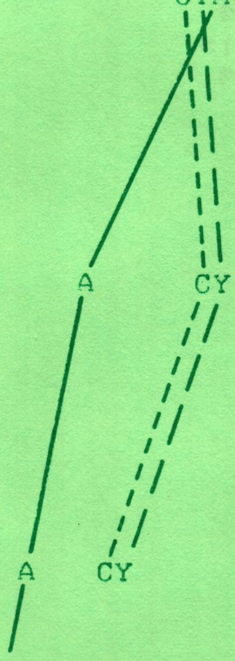
```
SPRING OF YEAR  1990
HERD SIZE= 673
A  AM  164               ?0
A  AF  226               ?0
Y  YM  38                ?0
Y  YF  32                ?0
C  CM  111               ?0
C  CF  102               ?0

SPRING OF YEAR  1991
HERD SIZE= 716
A  AM  175
A  AF  226
Y  YM  67
Y  YF  61
C  CM  97
C  CF  90

SPRING OF YEAR  1992
HERD SIZE= 752
A  AM  206               ?0
A  AF  248               ?0
Y  YM  58                ?0
Y  YF  54                ?0
C  CM  97                ?10
C  CF  89                ?0

SPRING OF YEAR  1993
HERD SIZE= 798
A  AM  227
A  AF  262
Y  YM  52
Y  YF  53
C  CM  106
C  CF  98

SPRING OF YEAR  1994
HERD SIZE= 846
A  AM  242
A  AF  274
Y  YM  58
Y  YF  59
C  CM  111
C  CF  102

 TOTAL HARVEST IN 20 YEARS IS 488 BUFFALO.
```

DRASTIC HARVESTS OF 1988 AND 1989 FORCED POPULATION TO FALL BELOW 800 OBJECTIVE.



*RUN #2* } **Here the student has selected *AUTOMATIC SAFEGUARDS* to protect the buffalo population. He is studying the effect of harvesting all of the yearlings.**

```
                    BUFFALO HERD MANAGEMENT

HAVE YOU USED BUFLO BEFORE (1=YES, 0=NO) ?1

WHICH POLICY DO YOU PREFER ?2

YEARS FOR OBSERVE, CHANGE POLICY, REPORT ?30,5,5

CARRYING CAPACITY ?40E6

STARTING YEAR= ?1900

WILL YOU INITIALIZE NUMBER OF BUFFALO BY
BREAKDOWN (1) OR TOTAL HERD (2) ?2
TOTAL BUFFALO IN HERD ?20E6

                   HARVEST        PERCENTAGE OF ORIGINAL POPULATION
SYM/GROUP  POP      QUOTA     0           100          200          300
---------  ---      -----     I------------I------------I------------I
SPRING OF YEAR  1900                       CYA
HERD SIZE= 20000000
A  AM  7560000       ?0
A  AF  6760000       ?0
Y  YM  1240000       ?1240000
Y  YF  920000        ?920000
C  CM  1820000       ?0
C  CF  1700000       ?0

SPRING OF YEAR  1905                  A     CY
HERD SIZE= 15656577
A  AM  4727484       ?0
A  AF  4746038       ?0
Y  YM  1234931       ?1234931
Y  YF  1139936       ?1139936
C  CM  1980258       ?0
C  CF  1827930       ?0

SPRING OF YEAR  1910               A   CY
HERD SIZE= 9772767
A  AM  2791526       ?0
A  AF  2802482       ?0
Y  YM  862907        ?862907
Y  YF  796529        ?796529
C  CM  1310048       ?0
C  CF  1209275       ?0
```



CHOICE TWO WILL STOP HARVESTING IF EITHER THE ADULTS FALL BELOW A CERTAIN LEVEL OR IF THE ADULT QUOTAS EXCEED A DANGER LEVEL. THUS THE HERD IS PROTECTED AGAINST EXCESSIVE HARVESTING.

```
SPRING OF YEAR  1915              A  CY
HERD SIZE= 5886906
A   AM  1648362          ?0
A   AF  1654831          ?0
Y   YM  535153           ?535153
Y   YF  493987           ?493987
C   CM  808378           ?0
C   CF  746195           ?0

SPRING OF YEAR  1920             A CY
HERD SIZE= 3517708
A   AM  973335           ?0
A   AF  977156           ?0
Y   YM  325178           ?325178
Y   YF  300164           ?300164
C   CM  489775           ?0
C   CF  452100           ?0
```

AFTER THIS MESSAGE IS TYPED, NO HARVESTING TAKES PLACE UNTIL THE HERD IS DECLARED OUT OF DANGER.

```
HERD PUT IN DANGER OF EXTINCTION DURING YEAR  1922
NO MORE HARVESTING UNTIL HERD IS SAFE.
IN ORDER TO LOWER CHANCE OF EXTINCTION,
DO YOU WANT TO CHANGE QUOTAS AT THIS TIME (1=YES, 0=NO) ?0

HERD OUT OF DANGER IN YEAR  1924
HARVESTING NOW PERMITTED
DO YOU WANT TO CHANGE QUOTAS AT THIS TIME (1=YES, 0=NO) ?0

HERD PUT IN DANGER OF EXTINCTION DURING YEAR  1924
NO MORE HARVESTING UNTIL HERD IS SAFE.
IN ORDER TO LOWER CHANCE OF EXTINCTION,
DO YOU WANT TO CHANGE QUOTAS AT THIS TIME (1=YES, 0=NO) ?0
```

EVEN THOUGH THE HERD HAS BEEN DECLARED TO BE IN DANGER AND HARVESTING HAS BEEN HALTED, QUOTAS ARE STILL ASKED FOR. HOWEVER, THESE QUOTAS WILL NOT BE IMPLEMENTED UNTIL THE HERD IS OUT OF DANGER.

```
SPRING OF YEAR  1925             AYC
HERD SIZE= 2543445
A   AM  736541
A   AF  726350
Y   YM  193730
Y   YF  178828
C   CM  368158
C   CF  339838

HERD OUT OF DANGER IN YEAR  1926
HARVESTING NOW PERMITTED
DO YOU WANT TO CHANGE QUOTAS AT THIS TIME (1=YES, 0=NO) ?1

SPRING OF YEAR  1926             ACY
HERD SIZE= 2654510
A   AM  808183           ?0
A   AF  787835           ?0
Y   YM  220895           ?220895
Y   YF  203903           ?203903
C   CM  329521           ?0
C   CF  304173           ?0

HERD PUT IN DANGER OF EXTINCTION DURING YEAR  1926
NO MORE HARVESTING UNTIL HERD IS SAFE.
IN ORDER TO LOWER CHANCE OF EXTINCTION,
DO YOU WANT TO CHANGE QUOTAS AT THIS TIME (1=YES, 0=NO) ?0
```

```
HERD OUT OF DANGER IN YEAR  1928
HARVESTING NOW PERMITTED
DO YOU WANT TO CHANGE QUOTAS AT THIS TIME (1=YES, 0=NO) ?0

HERD PUT IN DANGER OF EXTINCTION DURING YEAR  1928
NO MORE HARVESTING UNTIL HERD IS SAFE.
IN ORDER TO LOWER CHANCE OF EXTINCTION,
DO YOU WANT TO CHANGE QUOTAS AT THIS TIME (1=YES, 0=NO) ?0

HERD OUT OF DANGER IN YEAR  1930
HARVESTING NOW PERMITTED

SPRING OF YEAR  1930           ACY
HERD SIZE= 2573814
A  AM  795161
A  AF  761432
Y  YM  212248
Y  YF  195921
C  CM  316707
C  CF  292345

 TOTAL HARVEST IN 30 YEARS IS 35452096 BUFFALO.
```

PREVIOUSLY
ESTABLISHED
QUOTAS ARE
THEN IMPLEMENTED.

*RUN #3* { **Student has selected *TOTAL FREEDOM OF HERD CONTROL* and has driven the buffalo to extinction.**

```
               BUFFALO HERD MANAGEMENT

HAVE YOU USED BUFLO BEFORE (1=YES, 0=NO) ?1

WHICH POLICY DO YOU PREFER ?1

YEARS FOR OBSERVE, CHANGE POLICY, REPORT ?15,2,1

CARRYING CAPACITY ?10000

STARTING YEAR= ?1950

WILL YOU INITIALIZE NUMBER OF BUFFALO BY
BREAKDOWN (1) OR TOTAL HERD (2) ?2
TOTAL BUFFALO IN HERD ?3000

                   HARVEST        PERCENTAGE OF ORIGINAL POPULATION
SYM/GROUP  POP      QUOTA     0           100          200          300
---------  ---      -----     I------------I------------I------------I
SPRING OF YEAR  1950                       CYA
HERD SIZE= 3000
A  AM  1134          ?934
A  AF  1014          ?814
Y  YM  186           ?186
Y  YF  138           ?138
C  CM  273           ?273
C  CF  255           ?255

HERD PUT IN DANGER OF EXTINCTION DURING YEAR  1950
WE WILL CONTINUE AS YOU WISH.
```

IF TOTAL FREEDOM IS SELECTED, THIS MESSAGE SERVES ONLY AS A WARNING. HARVESTING CONTINUES.

```
SPRING OF YEAR  1951          Y A C
HERD SIZE= 535
A  AM  179
A  AF  179
Y  YM  0
Y  YF  0
C  CM  92
C  CF  85

YOU HAVE SUCCEEDED IN COMPLETELY DESTROYING
THE BUFFALO HERD BY  1951

 TOTAL HARVEST IN 2 YEARS IS 3135 BUFFALO.

DO YOU WANT ANOTHER RUN (1=YES, 0=NO) ?0
```

## IV. *BUFLO* PROGRAM LISTING

```
100 REM BUFLO -- PROGRAM SIMULATING THE RESOURCE MANAGEMENT OF
105 REM BUFFALO HERDS -- **THREE VARIABLE GRAPH VERSION
110 REM COPYRIGHT 1973, STATE UNIVERSITY OF NEW YORK
115 REM MODEL DEVELOPED BY L.BRAUN, J. FRIEDLAND
120 REM PROGRAMMED BY L. BRAUN, REVISED BY M. WEISNER AND B. ESRIG
125 REM LATEST REVISION: 11-28-73
130 DIMS(3),P(6),M(6),Q(6),H(6),Z(2)
135 DEFFNA(X)=SGN(SGN(X)+1)
140 DEFFNB(I)=INT(I)*FNA(INT(I))
145 PRINT"","BUFFALO HERD MANAGEMENT"
150 PRINT
155 PRINT"HAVE YOU USED BUFLO BEFORE (1=YES, 0=NO)";
160 INPUTD
165 PRINT
170 IFD=1THEN230
175 PRINT"CONSULT THE STUDENT MANUAL FOR INFORMATION ON"
180 PRINT"INITIALIZATION OF THE MODEL."
185 PRINT
190 PRINT"BUFLO USES THE FOLLOWING CODE:"
195 PRINT"      AM=ADULT MALES","AF=ADULT FEMALES"
200 PRINT"      YM=YEARLING MALES","YF=YEARLING FEMALES"
205 PRINT"      CM=CALF MALES","CF=CALF FEMALES"
210 PRINT
215 PRINT"THERE ARE TWO POLICIES OF HERD MANAGEMENT AVAILABLE."
220 PRINT"TOTAL FREEDOM OF HERD CONTROL (1)"
225 PRINT"OR AUTOMATIC SAFEGUARDS FOR HERD POPULATION (2)"
230 PRINT"WHICH POLICY DO YOU PREFER";
235 INPUTD
240 IF(D-1)*(D-2)<>0THEN230
245 PRINT
250 PRINT"YEARS FOR OBSERVE, CHANGE POLICY, REPORT";
255 INPUTZ0,P0,R0
260 IFP0*R0=0THEN175
265 PRINT
270 PRINT"CARRYING CAPACITY";
275 INPUTE
280 IFE<>INT(ABS(E))THEN270
285 IFE<=6E7THEN300
290 PRINT"CARRYING CAPACITY MUST BE LESS THAN 60 MILLION."
295 GOTO270
300 PRINT
305 LETH=0
310 LETF5=0
315 LETF1=0
320 PRINT"STARTING YEAR=";
325 INPUTT0
330 IFT0<>INT(ABS(T0))THEN320
335 LETT=T0
340 PRINT
345 RESTORE
350 PRINT"WILL YOU INITIALIZE NUMBER OF BUFFALO BY"
355 PRINT"BREAKDOWN (1) OR TOTAL HERD (2)";
360 INPUTG1
365 IFG1=1THEN390
370 IFG1<>2THEN350
```

```
375 PRINT"TOTAL BUFFALO IN HERD";
380 INPUTT5
385 IFT5<>INT(ABS(T5))THEN375
390 FORI=1TO6
395 READZ(1)
400 LETP(I)=INT(Z(1)*T5)
405 IFG1=2THEN435
410 PRINT"HOW MANY";
415 GOSUB900
420 PRINT" BUFFALO";
425 INPUTP(I)
430 IFP(I)<>INT(ABS(P(I)))THEN415
435 NEXTI
440 IFG1=1THEN450
445 LETP(6)=T5-P(1)-P(2)-P(3)-P(4)-P(5)
450 FORI=1TO6
455 READM(I)
460 LETH(I)=P(I)
465 NEXTI
470 PRINT
475 PRINTTAB(19);"HARVEST";
480 PRINTTAB(34);"PERCENTAGE OF ORIGINAL POPULATION"
485 PRINT"SYM/GROUP";TAB(11);"POP";(20);"QUOTA";
490 PRINTTAB(30);"0";TAB(42);"100";TAB(55);"200";TAB(68);"300"
495 PRINT"---------";TAB(11);"---";TAB(20);"-----";
500 PRINTTAB(30);"I------------I------------I------------I"
505 READZ(1),Z(2)
510 PRINT"SPRING OF YEAR ";T;
515 GOSUB935
520 PRINT"HERD SIZE=";
525 PRINTP(1)+P(2)+P(3)+P(4)+P(5)+P(6)
530 FORI=1TO6
535 GOSUB1055
540 GOSUB900
545 PRINTTAB(6);P(I);
550 IFF1=1THEN565
555 IFINT((T-T0)/P0)<>(T-T0)/P0THEN585
560 IFD+F5=3THEN585
565 PRINTTAB(20);
570 INPUTQ(I)
575 IFABS(INT(Q(I)))<>Q(I)THEN535
580 GOTO590
585 PRINT
590 NEXTI
595 PRINT
600 IFT-T0=Z0THEN1105
605 LETQ7=Q(1)*ABS(SGN(F5+D-3))
610 LETQ8=Q(2)*ABS(SGN(F5+D-3))
615 LETF0=(1-Q8/(P(2)+.1))*FNA(1-Q8/(P(2)+.1))
620 LETM9=(P(1)-Q7/2)*FNA(P(1)-Q7/2)
625 LETF9=(P(2)-Q8/2)*FNA(P(2)-Q8/2)
630 LETP9=(P(2)-Q8)*(1-M(2))*SGN(M9*F9)
635 IFF9/10<M9THEN645
640 LETP9=10*M9*(1-M(2))*SGN(M9*F9)*(1-Q8/2/(F9+.01))
645 IFD+F5=3THEN685
650 FOR I=1 TO 6
655 LETH=H+Q(I)
660 LETP(I)=P(I)-Q(I)
```

```
665 IFP(I)>=0 THEN 680
670 LETH=H+P(I)
675 LETP(I)=0
680 NEXTI
685 LETP7=P(1)+P(2)+P(3)+P(4)+P(4)+P(5)+P(6)
690 IFP7=0THEN1090
695 FORI=1TO2
700 LET P(I)=FNB((1-M(I))*P(I)+(1-M(I+2))*P(I+2)-1)
705 LET P(I+2)=FNB((1-M(I+4))*P(I+4)*F0+.5)
710 LET P(I+4)=FNB(Z(I)*P9*(1-.45*P7/E)+.5)
715 NEXTI
720 LETF1=0
725 IFP(1)<.019*ETHEN800
730 IFP(1)<Q(1)/2THEN800
735 IFP(2)<Q(2)/2THEN800
740 IFP(2)<.017*ETHEN800
745 IFF5=0THEN855
750 PRINT"HERD OUT OF DANGER IN YEAR ";T+1
755 LETF5=0
760 IFD=1THEN850
765 PRINT"HARVESTING NOW PERMITTED"
770 IFINT((T+1-T0)/P0)=(T+1-T0)/P0THEN850
775 REM SKIP IF POLICY YEAR
780 PRINT"DO YOU WANT TO CHANGE QUOTAS AT THIS TIME (1=YES, 0=NO)";
785 INPUTF1
790 IFF1*(F1-1)<>0THEN780
795 GOTO850
800 IFF5=1THEN855
805 REM DANGER OF EXTINCTION
810 PRINT"HERD PUT IN DANGER OF EXTINCTION DURING YEAR ";T
815 LETF5=1
820 IFD=1THEN845
825 PRINT"NO MORE HARVESTING UNTIL HERD IS SAFE."
830 IFP(1)+P(2)=0THEN780
835 PRINT"IN ORDER TO LOWER CHANCE OF EXTINCTION,"
840 GOTO780
845 PRINT"WE WILL CONTINUE AS YOU WISH."
850 PRINT
855 LETT=T+1
860 IFT-T0<>Z0THEN880
865 LETF1=0
870 LETP0=2E7
875 GOTO510
880 IFINT((T-T0)/P0)=(T-T0)/P0THEN510
885 IFINT((T-T0)/R0)=(T-T0)/R0THEN510
890 IFF1=1THEN510
895 GOTO600
900 PRINT"  ";
905 GOSUB1055
910 IF I/2=INT(I/2)THEN925
915 PRINT"M";
920 GOTO930
925 PRINT"F";
930 RETURN
935 FORI=2TO6STEP2
940 IFH(I)+H(I-1)<>0 THEN 955
945 LETS(I/2)=43
```

```
950 GOTO960
955 LETS(I/2)=(P(I)+P(I-1))*13/(H(I)+H(I-1))+30
960 NEXTI
965 LETI1=1
970 FORJ=1TO3
975 FORI=1TO3
980 IFS(I)>S(I1)THEN990
985 LETI1=I
990 NEXTI
995 LETI=2*I1
1000 IFS(I1)>70THEN1035
1005 PRINTTAB(S(I1));
1010 GOSUB1055
1015 LETS(I1)=4E8
1020 NEXTJ
1025 PRINT
1030 RETURN
1035 PRINTTAB(68);
1040 GOSUB1055
1045 PRINT"->";
1050 GOTO1015
1055 IF I>2 THEN 1065
1060 PRINT"A";
1065 IF ABS(I-3.5)>.5 THEN 1075
1070 PRINT"Y";
1075 IF I<5 THEN 1085
1080 PRINT"C";
1085 RETURN
1090 PRINT"YOU HAVE SUCCEEDED IN COMPLETELY DESTROYING"
1095 PRINT"THE BUFFALO HERD BY ";T
1100 LETT=T+1
1105 PRINT
1110 PRINT" TOTAL HARVEST IN";T-T0;"YEARS IS";H;"BUFFALO."
1115 DATA.378,.338,.062,.046,.091
1120 DATA 0
1125 DATA.1,.1
1130 DATA.25,.25
1135 DATA.4,.4
1140 DATA.52,.48
1145 PRINT
1150 PRINT"DO YOU WANT ANOTHER RUN (1=YES, 0=NO)";
1155 INPUTD
1160 IFD=1THEN230
1165 END
```

## V. LIST OF VARIABLES

| Variable | Meaning |
|---|---|
| D | Policy decision flag |
| E | Environmental carrying capacity |
| F0 | Proportion of the adult females harvested |
| F1 | Off-year policy set flag |
| F5 | Harvesting - Herd Condition flag |
| F9 | Number of adult females present at time of mating |
| G0 | Instruction flag |
| G1 | Temporary response and number holder |
| H | Total harvest |
| H(1)-H(6) | Initial population of each cohort |
| I | Index |
| II | Index |
| J | Index |
| M9 | Number of adult males present at time of mating |
| M(1)-M(6) | Mortality (% deaths/year) of each age-sex group |
| P0 | Policy adjustment interval |
| P9 | Number of pregnant adult females |
| Q7 | Effective adult male harvest |
| Q8 | Effective adult female harvest |
| Q(1)-Q(6) | Harvest quota/year for each age-sex group |
| R0 | Report interval |
| S(1)-S(3) | Graph TAB location |

| Variable | Meaning |
|---|---|
| T | Year number |
| T0 | Initial Year |
| T5 | Total number of buffalo in initial herd |
| Z0 | Time interval |
| Z1 | Proportion of calves born male |
| Z2 | Proportion of calves born female |

| When Subscript Equals | Variable Refers To |
|---|---|
| 1 | Adult Males |
| 2 | Adult Females |
| 3 | Yearling Males |
| 4 | Yearling Females |
| 5 | Calf Males |
| 6 | Calf Females |

# VI. FORMULAS

## A. Population Structure

$$P_7 = P_1 + P_2 + P_3 + P_4 + P_5 + P_6$$

Where $P_7$ equals the total population and $P_1$ through $P_6$ represent Adult Males, Adult Females, Yearling Males, Yearling Females, Calf Males and Calf Females respectively.

## B. Fertility and Birth

1) Number of pregnancies carried through to spring

If Adult Females are at least ten times as numerous as Adult Males:

$$P_9 = (P_2 - Q_8) * (1 - M_2)$$

Where $P_9$ equals pregnancies, $Q_8$ represents effective female Harvest and $M_2$ equals mortality in Adult Females.

If Adult Females are more numerous than ten times the number of Adult Males, then:

$$P_9 = 10 * M_9 * (1 - M_2) * \left(1 - \frac{Q_8/2}{F_9}\right)$$

Where $M_9$ and $F_9$ equal the number of Adult Males and Females present at the time of mating.

2) Births

$$P_5 = Z_1 * P_9 * [1 - (.45 * P_7/E)]$$

$$P_6 = Z_2 * P_9 * [1 - (.45 * P_7/E)]$$

Where E equals the environmental carrying capacity, $Z_1$ and $Z_2$ equal the proportion of male and female births, respectively.

### C. Aging and Mortality

$$P_1 = [P^1_1 * (1 - M_1) + P^1_3 * (1 - M_3) - 1]$$

$$P_2 = [P^1_2 * (1 - M_2) + P^1_4 * (1 - M_4) - 1]$$

Where primed variables represent old values and unprimed variables represent the resultant values.

$$P_3 = [P_5 * (1 - M_5) * F_0]$$

$$P_4 = [P_6 * (1 - M_6) * F_0]$$

Where $F_0$ equals the proportion Adult Females harvested during the preceding year.

### D. Harvest

$$H = H^1 + Q_1 + Q_2 + Q_3 + Q_4 + Q_5 + Q_6$$

If any quota ($Q_1 - Q_6$) exceeds the available population, then

$$Q_1 = P_1$$

Therefore, the populaiion is lowered by its specific age-sex group quota or its propulation, if quota exceeds the available population

$$P_1 = P^1_1 - Q_1$$

## VII. *BUFLO* MODEL ASSUMPTIONS

1) Nonhunting mortality is independent of hunting quota. For any single year, 10% of the adults, 25% of the yearlings and 40% of the calves will die. All mortality is assumed to take place after the hunting season.

   Increased mortality occurs in calves as adult females are harvested. This is based on the assumption that calves are dependent on their mothers during the entire first year.

2) All harvesting takes place during late spring, summer and early autumn. Approximately one half of the quota has been harvested by mating season.

3) As total population approaches the carrying capacity, the birth rate falls to 55% of its maximum value. It is assumed that all individuals have an equal environmental impact.

4) It is assumed that each adult male bull can successfully mate with up to 10 adult females.

5) If the quota exceeds the population of a particular sex-age group, the entire sex-age group will be harvested. One half of the original quota will be harvested before mating season.

6) The herd is defined as "in danger of extinction" if the population of adult males or adult females falls below one twentieth of the normal population at the carrying capacity.

7) No harvest is taken the last year of the program. A report is given for the spring of the year and then the program is terminated. (If the student wishes to continue this run, he may initialize another run from the last report, with the same results as if the run had been continued.)

8) There is no immigration or emigration of buffalo from the area being studied.

9) It is assumed that the buffalo assemble in a single interacting herd, especially as the numbers become small.

10) No female may become pregnant until the third year. A gestation period of nine and one half months places the first possible birth in the female's fourth year. After the fourth year, a cow may produce one birth per year.

11) Males are assumed to play no role in raising or protecting the young.

12) There is no fixed maximum lifespan for the buffalo, but most buffalo are assumed to die before old age (approximately 30 years).

13) If the buffalo herd is initialized by "TOTAL HERD" (Choice 2), the cohorts are set:

| | |
|---|---|
| 37.8% | Adult male |
| 33.8% | Adult female |
| 6.2% | Yearling male |
| 4.6% | Yearling female |
| 9.1% | Calf male |
| 8.5% | Calf female |

14) 52% of all live births are male and 48% of all live births are female.

## VIII. FURTHER STUDENT INVESTIGATIONS

### 1) Effect of Changing Calf Mortality

Mortality of calves is always highest in the winter months, but this mortality may vary greatly with the severity of the weather. The effects of higher or lower calf mortality may be simulated by altering two values stored in line 1135 of the *BUFLO* program. Currently line 1135 reads 1135 DATA.4,.4 which represents a calf mortality equal to 40%. The first number represents mortality in male calves and the second is for female calves. These numbers may be replaced with any number from 0 to 1, where 0 represents no mortality, and 1 represents complete mortality.

For example, if you wish to set both male and female mortality to 60%, you would type:

```
1135 DATA.60,.60
```

before you type RUN".

2) The Effect of Differing Sex Ration in Births

*BUFLO* assumes that 52% of the live births will be male and 48% female. This information is stored in line 1140 as DATA.52,.48. You can reset this ratio by choosing any two positive numbers that total one.

For example, if you wish to examine the consequences of 25% male births and 75% female births, you would type:

```
1140 DATA.25,.75
```

Remember to use decimal numbers and place the male number first. This should be done just before typing "RUN".

See also: "ADDITIONAL INVESTIGATION SUGGESTIONS" in *STUDENT MANUAL*, p.16.

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